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Indian Standard

SPECIFICATION FOR LAMINATIONS FOR TRANSFORMERS AND INDUCTORS FOR USE IN TELECOMMUNICATION AND ELECTRONIC EQUIPMENT

PART I GENERAL REQUIREMENTS AND TESTS

UDC 621·3·042·2:621·314·21:621·318·43:621·38/·39·038

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5 *November* 1987

AMENDMENT NO. 1 MAY 2002
TO
IS 11794 (PART 1) : 1986 SPECIFICATION FOR LAMINATIONS FOR TRANSFORMERS AND INDUCTORS FOR USE IN TELECOMMUNICATION AND ELECTRONIC EQUIPMENT

PART 1 GENERAL REQUIREMENTS AND TESTS

[This amendment is largely based on Amendment 1(1991) to IEC 60740(1982) issued by International Electrotechnical Commission (IEC).]

(*Page* 8, *clause* **11.1**) — Substitute the following for the existing clause:

'**11.1 General** — For single-phase transformers, one of the circuits of Fig. 1 should be used. The measuring conditions shall be in accordance with the values specified in Table 5. There is a choice of values of peak flux density for some laminations, and the value used shall be stated in any relevant test certificate, together with the appropriate frequency.

For three-phase transformers, the measuring conditions of Table 5 shall apply, but the arrangements given in **13.2** of IS 8644: 2001 Specification for Strip-wound cut cores of grain oriented silicon-iron alloy, used for electronic and telecommunications equipment (*first revision*) shall be used, and the calculations made accordingly.'

(LTD 13)

Reprography Unit, BIS, New Delhi, India

Indian Standard

SPECIFICATION FOR LAMINATIONS FOR TRANSFORMERS AND INDUCTORS FOR USE IN TELECOMMUNICATION AND ELECTRONIC EQUIPMENT

PART 1 GENERAL REQUIREMENTS AND TESTS

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(*Continued on page* 2)

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Indian Standard

SPECIFICATION FOR LAMINATIONS FOR TRANSFORMERS AND INDUCTORS FOR USE IN TELECOMMUNICATION AND ELECTRONIC EQUIPMENT

PART 1 GENERAL REQUIREMENTS AND TESTS

0. FOREWORD

0.1 This Indian Standard (Part 1) was adopted by the Indian Standards Institution on 28 July 1986, after the draft finalized by the Magnetic Components and Ferrite Materials Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard deals with laminations of various shapes, made from magnetic sheets or alloys of specified composition and thicknesses, their marking and packing, and also simple test methods for determining the electrical properties of cores made from such laminations. The principal application of these laminations is for transformer and inductors used in telecommunication and electronic equipment employing similar techniques.

0.3 The preferred ranges of laminations are covered in Part 2 of this series.

0.4 This standard is based on IEC Pub 740 (1982), 'Laminations for transformers and inductors for use in telecommunication and electronic equipment', issued by the International Electrotechnical Commission (IEC).

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part 1) specifies general requirements, namely, mechanical and electrical characteristics and methods of tests for laminations for transformers and inductors for use in telecommunication and electronic equipment.

SECTION 1 GENERAL

2. TERMINOLOGY

2.1 For the purpose of this standard, the following definitions, in addition to those given in IS : 1885 (Part 31)-1971† and IS : 1885 (Part 41)-1975‡ shall apply.

2.2 Lamination — A lamination as produced from a magnetic steel or alloy sheet, usually consisting of one piece or two pieces together, forming one complete layer of a laminated core.

2.3 Stacking Factor (α) — The ratio of the metal cross-section to the total stack or built up cross-section.

NOTE — The terms 'lamination factor' or 'space factor' are sometimes used instead of 'stacking factor'.

SECTION 2 MECHANICAL CHARACTERISTICS

3. MATERIALS AND THICKNESS

3.1 Materials — Laminations shall be made from any one of the materials specified in Table 1.

3.2 Nominal Thickness — Laminations thicknesses shall be selected from one of the values specified in Table 2, according to the material in use.

---

*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary : Part 31 Magnetism.

‡Electrotechnical vocabulary : Part 41 Non-reciprocal electromagnetic components.

TABLE 1 MAGNETIC STEEL AND ALLOYS USED FOR LAMINATIONS

(*Clauses* 3.1 *and* 8)

MATERIAL	APPROXIMATE COMPOSITION IN ADDITION TO IRON
(1)	(2)
Low carbon mild steel	—
Silicon steel, non-oriented (*see* IS : 648-1980*)	0·5% to 4·5% silicon
Silicon steel, oriented (*see* IS : 3024-1965†)	3% silicon
Nickel-iron alloys	72% to 83% nickel 45% to 50% nickel (both oriented and non-oriented) 35% to 40% nickel
Iron-cobalt alloys	47% to 50% cobalt (isotropic)

*Specification for non-oriented electrical steel sheets and strips for magnetic circuits (*third revision*).

†Specification for electrical steel sheets (oriented).

TABLE 2 LAMINATION THICKNESS

(*Clause* 3.2)

MATERIAL DESIGNATION	THICKNESS IN MILLIMETRES (*see* Note 1)								
	0·65	0·50	0·35	0·30	0·27	0·20	0·15	0.10	0·05
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Low carbon mild steel and silicon steel, non-oriented	⊗	×	×					⊗	
Silicon steel, oriented (*see* Note 2)			×	×	×		×	×	⊗
Nickel-iron alloys & iron-cobalt alloys			×	⊗		×	⊗	×	⊗
Nickel-iron alloys, oriented (45 to 50 percent)								×	⊗

NOTE 1 — X indicates a preferred value.

NOTE 2 — Anv thickness within the range 0·27 to 0·35 mm is a preferred value; this arises because several grades of material are produced in different thicknesses.

3.3 Nominal Stacking Factor — Nominal stacking factor, determined for interleaved stacks of laminations, assembled one by one and subjected to a uniform pressure of 15 kN/m² perpendicular to the plane of one lamination, shall not be less than the values specified in Table 3, according to the material in use and its nominal thickness.

4. GENERAL APPEARANCE AND CONDITIONS

4.1 Laminations shall be clean, free from rust and oil or cutting fluids. They shall be flat and free from burrs and distortion (to enable the requirements of **4.3** to be met).

4.2 Heat treated laminations shall be free from contaminating deposits.

4.3 Insulation shall be complete and uniform.

5. DIMENSIONS AND TOLERANCES

5.1 The dimensions and tolerances of the preferred ranges of laminations are specified in IS : 11794 (Part 2/Sec 1 to 7)*. The tolerance on the lamination thickness equals that for the sheets.

Assembly fixing holes, when necessary, shall be placed at the intersecting points of the centre lines of the outer limbs.

5.2 The tolerances shall be in accordance with IS: 919 (Part 1)-1963†. The values corresponding to the reference designations at the head of each

---

*Laminations for transformers and inductors for use in telecommunication and electronic equipment : Part 2 Preferred ranges of laminations, Sec 1 to 7.

†Recommendations for limits and fits for engineering: Part 1 General engineering (*first revision*).

TABLE 3 MATERIAL THICKNESSES AND STACKING FACTORS

(*Clauses* 3.3 *and* 9.2.2)

MATERIAL THICKNESS mm	NOMINAL STACKING FACTORS		
	Low Carbon Mild Steel and Non-Oriented Silicon Steel	Oriented Silicon Steel	Nickel-Iron and Cobalt-iron Alloys
(1)	(2)	(3)	(4)
0·65	0·95	—	—
0·50	0·95	—	—
0·35	0·94	0·95	0·94
0·30	—	0·94	0·92
0·27	—	0·93	—
0·20	—	—	0·90
0·15	—	0·92	0·87
0·10	0·90	0·90	0·85
0·05	—	0·88	0·80

TABLE 4 TOLERANCES

(*Clause* 5·2)

SIZE RANGE	TOLERANCE CODE LETTERS				
	IT 10	IT 11	IT 12	IT 13	IT 14
(1)	(2)	(3)	(4)	(5)	(6)
mm	µm	µm	µm	µm	µm
1-3	40	60	100	140	250
3-6	48	75	120	180	300
6-10	58	90	150	220	360
10-18	70	110	180	270	430
18-30	84	130	210	330	520
30-50	100	160	250	390	620
50-80	120	190	300	460	740
80-120	140	220	350	540	870
120-180	160	250	400	630	1000
180-250	185	290	460	720	1150
250-315	210	320	520	810	1300
315-400	230	360	570	890	1400
400-500	250	400	630	970	1550

NOTE — The tolerance code indicates the value of the tolerance in relation to the nominal dimension. For example in Table 1 of IS : 11794 (Part 2/Sec 1)-1986* YEI-10, the tolerance on *b* (20 mm $\pm \frac{1}{2}$ IT 12) is $\frac{1}{2} \times 210\ \mu\text{m} = \pm 0{\cdot}105$ mm; for *e* (20 mm $\pm \frac{1}{2}$ IT 14), it is $\pm \frac{1}{2} \times 520\ \mu\text{m} = \pm 0{\cdot}26$ mm. In Table 1 of IS : 11794 (Part 2/Sec 2)-1986*, YEx 2-2, the tolerance on *d* ($2{\cdot}4\ \text{mm}\ {}^{+0}_{-\text{IT}\,11}$) is ${}^{+0}_{-0{\cdot}06}$ mm.

*Laminations for transformers and inductors for use in telecommunication and electronic equipment: Part 2 Preferred ranges of laminations, Sec 1 Lamination type YEI-1 and Sec 2 Lamination type YEx-2

column of dimensions in the tables of IS : 11794 (Part 2/Sec 1 to 7)* are given in Table 4.

5.3 The symmetry tolerances of dimensions *a* and *e* of the tables of IS : 11794 (Part 2/Sec 1 to 7)* with respect to the centre line of the centre limb shall not exceed half the tolerance specified for the width of the centre limb (dimension *d*).

5.4 When sizes of laminations are used which are larger than those specified in the tables of IS : 11794 (Part 2/Sec 1 to 7)* the tolerances indicated in the headings of the columns shall still apply. Such laminations should be of the same shape as those in the tables and the ratios indicated in the tables should be maintained.

---

*Laminations for transformers and inductors for use in telecommunication and electronic equipment: Part 2 Preferred ranges of laminations, Sec 1 to 7.

6. DESIGNATION OF LAMINATIONS

6.1 All designations of laminations consist of a combination of a letter symbol identifying the shape and a number representative of the size of the lamination.

6.2 The designation consists of :

a) the letter Y indicating laminations in general,

b) one or more letters identifying the shape,

c) a serial number which distinguishes different ranges having the same letter designations, and

d) a dash followed by the approximate width *d* of the (centre) limb in millimetres.

6.2.1 Typical examples are :

YEI 1-40
YEE 3-20
YM 1-23

7. PACKAGING AND MARKING

7.1 The laminations shall be packed for transit in such a manner that no deterioration will occur.

7.2 Unless otherwise specified, both parts of two-part laminations shall be packed together.

7.3 All packages or boxes shall be marked with the following information:

a) The lamination designation and thickness (for shape YM, also the air gap length),

b) The quantity by mass or by approximate count,

c) The material in accordance with Table 1, and

d) The manufacturer's lot identification or date of manufacture.

Example of marking are :
Lamination : YEI 1-40, thickness 0·35 mm
Quantity : 100 kg
Material : silicon steel, oriented
Date of manufacture : 1/86

SECTION 3 ELECTRICAL TEST

8. GENERAL

Electrical tests for stacked laminations shall be carried out for the appropriate materials specified in Table 1 according to the test parameters specified in Tables 5, 6 and 7.

The following tests are intended as guidance to the simple testing of regularly used parameters.

9. EFFECTIVE PARAMETERS

9.1 The core constants (*see* IS : 7616-1974*) are calculated in general as follows :

$$C_1 = \frac{l}{A} \qquad C_2 = \frac{l_{Fe}}{A^2}$$

In the case of laminations, these constants are defined by :

$$C_1 = \frac{l_{Fe}}{A_{Fe}} \qquad C_2 = \frac{l_{Fe}}{A^2_{Fe}}$$

where

l_{Fe} = magnetic path length calculated as in **9.2.1.**

A_{Fe} = core area taking into account the stacking factor α (*see* **9.2.2**). Further, the core volume $V_{Fe} = l_{Fe} \times A_{Fe}$ and the core mass $m_{Fe} = V_{Fe} \times \rho$

where

ρ = density of the magnetic material.

9.2 The effective parameters of laminated cores with square cross-sections and a stacking factor of 0·95 are given in the tables of IS : 11794 (Part 2/Sec 1 to 7)† for the preferred laminations.

9.2.1 The magnetic path length l_{Fe} is calculated as the arithmetic mean of the longest and the shortest field path length of the core neglecting radii.

The details of calculation for each core are given in IS : 11794 (Part 2/Sec 1 to 7)†.

9.2.2 The right section core area A_{Fe} is calculated as the product of centre limb width, stacking height and stacking factor $A_{Fe} = d \times h \times \alpha$. For the associated tables of IS : 11794 (Part 2/Sec 1 to 7)†, $h = d$, $\alpha = 0{\cdot}95$ so that $A_{Fe} = 0{\cdot}95\, d^2$.

For other stacking heights and stacking factors (*see* Table 3), the values in the tables should be multiplied by :

$$\frac{h}{d} \times \frac{\alpha}{0{\cdot}95} \text{ for } A_{Fe}\text{, and}$$

$$\frac{d}{h} \times \frac{0{\cdot}95}{\alpha} \text{ for } C_1$$

Alternatively, for a given core stack, the core area may be determined as follows :

$$\text{For YEI, YEx, YUI and YM : } A_{Fe} = \frac{m_{Fe}}{l_{Fe}\,\rho}$$

$$\text{for YED : } A_{Fe} = \frac{0{\cdot}9\, m_{Fe}}{l_{Fe}\,\rho}$$

---

*Guide for calculation of the effective parameters of magnetic piece parts.

†Laminations for transformers and inductors for use in telecommunication and electronic equipment: Part 2 Preferred ranges of laminations, Sec 1 to 7.

10. GENERAL CONDITIONS FOR ELECTRICAL MEASUREMENTS

10.1 Unless otherwise stated, all tests shall be carried out at the standard atmospheric conditions for testing in accordance with IS : 9000 (Part 1) - 1977*.

Test certificates shall state what test conditions have been used.

10.2 The test coils shall be suitable for a square stack of laminations to be tested. The numbers of turns N_1 and N_2 (*see* Fig. 1 and 2), shall be adapted to the instruments used. The voltage winding N_2 shall be the inner winding and shall be as close as possible to the core and its resistance R_2 shall be small compared to the resistance of its load. The resistance in the supply circuit, including R_1 and the resistance of the current measuring device (ammeter, current amplifier or precision resistor), should be so small as not to give any appreciable distortion of the voltage.

10.3 The laminations shall be physically in accordance with the requirements of Section 2 of this standrad and IS : 11794 (Part 2/Sec 1 to 7)† and shall be selected at random from those that are fully processed for the end application. They shall be interleaved throughout the stack one by one and shall consist of an equal number of both parts in the case of two-part laminations. During the test, the lamination stack should be subjected to a uniform pressure of 15 kN/m² perpendicular to the plane of one lamination.

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*Basic environmental testing procedures for electronic and electrical items : Part 1 General.

†Laminations for transformers and inductors for use in telecommunication and electronic equipment : Part 2 Preferred ranges of laminations, Sec 1 to 7.

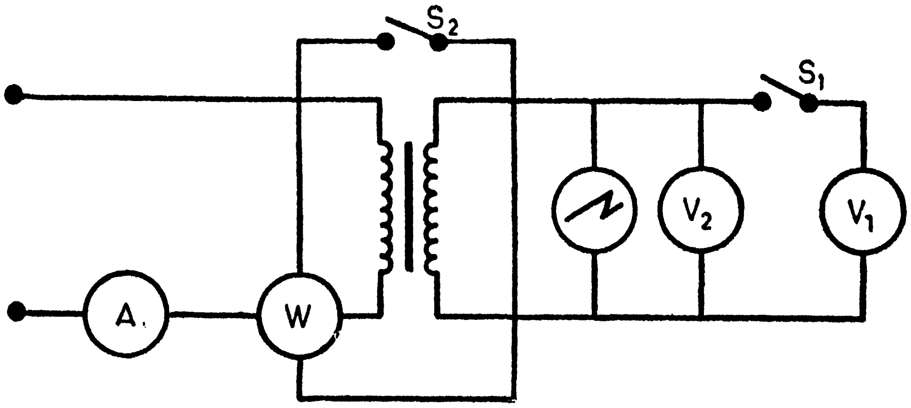

FIG. 1A MEASUREMENTS AT HIGH FIELD STRENGTH : DIRECT METHOD

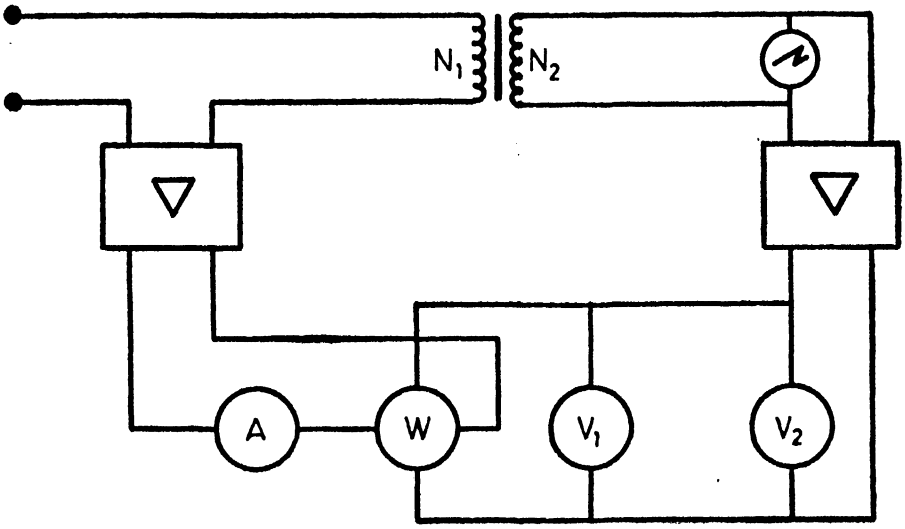

FIG. 1B MEASUREMENTS AT HIGH FIELD STRENGTH : INDIRECT METHOD

The number of laminations to be inserted in the test coil shall be sufficient to form not less than half a square stack.

10.4 In order to obtain comparable results, sinusoidal flux density shall be used for the measurements. During the test, the harmonic content shall not exceed 6 percent. When two voltmeters V_1 and V_2 are connected in parallel to the voltage winding N_2, the former measuring the average value and the latter measuring the rms value, the form factor may be determined from the ratio of the rms value to the average value. When this form factor does not deviate from 1·11 by more than 1 percent and at the same time the waveshape as observed on the oscilloscope does not show obvious distortion, the harmonic content of the secondary voltage and hence of the flux density will be sufficiently small.

NOTE — Average voltage may be determined by means of a rectifying moving coil voltmeter. If, as is common, this instrument is scaled in volts rms, the average voltage may be obtained by dividing the reading by 1·11.

In order to measure rms voltages for the determination of form factors, the user should ensure that the meter used registers true rms values.

11. MEASUREMENT AT HIGH FIELD STRENGTH

11.1 General — One of the circuits of Fig. 1 may be used. The measuring conditions shall be in accordance with the values specified in Table 5. There is a choice of values of peak flux density for some laminations and the value used shall be stated in any relevant test certificate, together with the appropriate frequency.

11.2 Measurement of Power Loss — When the circuit of Fig. 1A is used, both switches are closed for the determination of form factor (*see* **10.4**). Switch S_1 is then opened and the primary voltage adjusted so that the reading of the secondary voltage U_2 on the average sensing voltmeter V_2 has the value calculated from the equation :

$$U_2 = \frac{2\pi f}{\sqrt{2}} A_{Fe} \hat{B} \frac{N_2}{1 + R_2\left[\frac{1}{R_V} + \frac{1}{R_W}\right]}$$

where

f = test frequency,

A_{Fe} = core area (*see* 9.1),

$\hat{B}$ = test peak flux density,

N_2 = number of turns of the voltage winding,

R_2 = resistance of the voltage winding N_2,

R_V = resistance of the voltmeter V_2, and

R_W = resistance of the voltage winding of the wattmeter.

With switch S_1 open and switch S_2 closed, the wattmeter is read. Neglecting the copper losses in winding N_1 and in the ammeter, the power loss P_L is calculated from the measured power P_m as follows :

$$P_L = \left[1 + R_2\left(\frac{1}{R_V} + \frac{1}{R_W}\right)\right] \left[\frac{N_1}{N_2}P_m - U_2^2\left(\frac{1}{R_V} + \frac{1}{R_W}\right)\right]$$

NOTE — The result of the measurement is often expressed in terms of power loss (mass) density $\frac{P_L}{m}$ in W/kg, where m is the core mass.

When instruments are used which incorporate linear preamplifiers (Fig. 1 B) or similar devices with very high input impedance for voltage measurements, and with direct reading of the actual values of voltage and power, these formulae reduce to the following expressions :

$$U_2 = \frac{2\pi f}{\sqrt{2}} A_F \hat{B} N_2 \text{ and } P_L = \frac{N_1}{N_2}P_m$$

When these impedances are not extremely high but much higher than R_2, the following simplified formula may be used :

$$P_L = \frac{N_1}{N_2} P_m - U_2^2\left(\frac{1}{R_V} + \frac{1}{R_W}\right)$$

NOTE — When no direct reading is possible, for example, when external preamplifiers are used, the gains of these amplifiers should be taken into account.

TABLE 5 CONDITIONS FOR MEASUREMENT OF POWER LOSS AND TOTAL APPARENT POWER

(*Clauses* 8 *and* 11.1)

MATERIAL	THICKNESS	FREQUENCY	PEAK FLUX DENSITY, T
(1)	(2)	(3)	(4)
	mm	Hz	
Low carbon mild steel and non-oriented silicon steel	0·35 to 0·65	50 or 60	1·0 1·5
	0·1	400	1·0
Oriented silicon steel	0·27 to 0·35	50 or 60	1·5
	0·1 to 0·15	400	1·5
Iron-cobalt alloys	0·2 and 0·35	50 or 60	2·0
	0·1	400	1·7

11.3 Measurement of Total Apparent Power — When the circuit of Fig. 1A is used, both switches are closed for the determination of form factor (*see* **10.4**). Switch S_1 is then opened and the primary voltage adjusted as described in **11.2.** With both switches S_1 and S_2 open, the primary current I_1 and the secondary voltage U_2 are measured. The total apparent power is calculated from the equation :

$$S = U_2 \frac{R_V + R_2}{R_V} \frac{N_1}{N_2} I_1$$

NOTE — The result of the measurement is often expressed in terms of total apparent power density $\frac{S}{m}$ in VA/kg, where m is the core mass.

When instruments are used which incorporate linear preamplifiers (Fig. 1B) or similar devices with very high input impedance for voltage measurements, with direct reading of the actual of values of voltage and power, this formula reduces to the following expression :

$$S = U_2 \frac{N_1}{N_2} I_1$$

NOTE — When no direct reading is possible, for example, when external preamplifiers are used, the gains of these amplifiers have to be taken into account.

12. MEASUREMENT AT LOW AND MEDIUM FIELD STRENGTHS

12.1 General — The circuit of Fig. 2 should be used. The measuring conditions shall be in accordance with the values specified in Tables 6 and 7. There is a choice of values of frequency, peak flux density or field strength amplitude for some laminations and the values used shall be stated in any relevant test certificate.

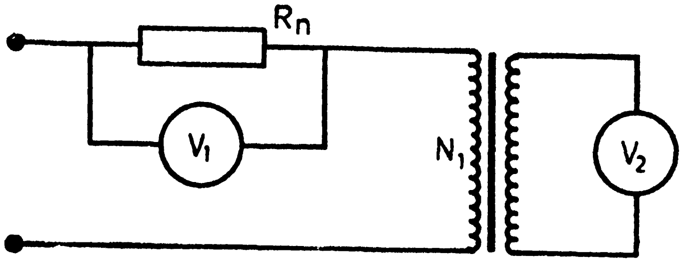

FIG. 2 MEASUREMENTS AT LOW AND MEDIUM FIELD STRENGTHS

TABLE 6 CONDITIONS FOR MEASUREMENT OF AMPLITUDE PERMEABILITY OF CORES USING LAMINATIONS OF LOW CARBON MILD STEEL OR SILICON STEEL

(*Clauses* 8 *and* 12.1)

THICKNESS (1) mm	FREQUENCY (2) Hz	PEAK FLUX DENSITY, T (3)
0·1 to 0·65	50 or 60	0·1 1·0

TABLE 7 CONDITIONS FOR MEASUREMENT OF AMPLITUDE PERMEABILITY OF CORES USING LAMINATIONS OF NON-ORIENTED NICKEL IRON ALLOY

(*Clauses* 8 *and* 12.1)

NICKEL-IRON ALLOY (1)	THICKNESS, mm (2)	FREQUENCY, Hz 50/60 (3)	FREQUENCY, Hz 300/400 (4)	FREQUENCY, Hz 1000 (5)	AMPLITUDE OF FIELD STRENGTH, A/m (6)
72 to 83% nickel	0·05	×	×	×	0·2 or 0·4
	0·10	×	×		
	0·20	×	×		
	0·35	×			
45 to 53% nickel (non-oriented)	0·10	×	×		0·4
	0·20	×			
	0·35	×			
35 to 40% nickel	0·05	×	×	×	0·4 or 1·6
	0·10	×	×		
	0·20	×			
	0·35	×			

NOTE — A cross in a frequency column indicates that the frequency is preferred for the measurement of amplitude permeability on laminations of that type of nickel-iron alloy grade and thickness.

12.2 Measurement of Amplitude Permeability — The primary voltage is adjusted so that the reading of the secondary voltage U_2 on the voltmeter V_2 has the value calculated from the formula:

$$U_2 = \frac{2\pi f}{\sqrt{2}} A_{Fe} \hat{B} N_2 \left(\frac{R_v}{R_v + R_2} \right)$$

where the symbols have the significance explained in **11.2**.

The peak value $\hat{I}_1$ of the primary current is measured by means of a peak voltmeter connected across a known precision resistor R_n in the primary circuit or by means of a probe. The amplitude permeability μ_a is deived from the equation:

$$\mu_a = \frac{1}{\mu_0} \frac{\hat{B}}{H} = \frac{1}{\mu_0} \frac{U_2 \sqrt{2}}{\hat{U}_n} \frac{C_1}{2\pi f} \frac{1}{N_1 N_2} \frac{R_v + R_2}{R_v} R_n$$

where

μ_0 = magnetic constant,

$\hat{U}_n$ = peak value of voltage measured across R_n, and

C_1 = core constant (cm^{-1}) (*see* **9.1**).

NOTE 1 — For very small current, μ_a tends towards the initial permeability μ_i.

NOTE 2 — In some cases, it is convenient to use the complex permeability and its components.

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Printed at Delhi Printers, Delhi, India